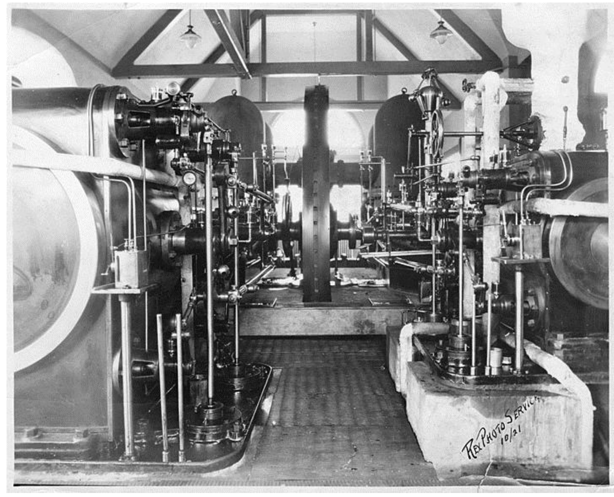
Tracking Pathogens to Their Source

What's the issue?

Pathogens from human sewage and animal waste are among the oldest and most ubiquitous drinking water contaminants. In the late-1800s, the advent of modern epidemiology and germ theory led to the understanding that many diseases are caused by waterborne microorganisms rather than harmful "miasmas" (vapors) in the air. By the early-1900s, many American municipalities had taken steps to keep drinking water sources separate from sewage sources and were adopting basic filtration and disinfection techniques. These actions improved the microbial quality of drinking water so dramatically that it is still considered one of the greatest global advances in public health. Half of the decline in mortality from 1900 to 1940 – the largest recorded decline in mortality in United States history – is attributed to the introduction of these basic wastewater and drinking water practices (Cutler and Miller, 2005).



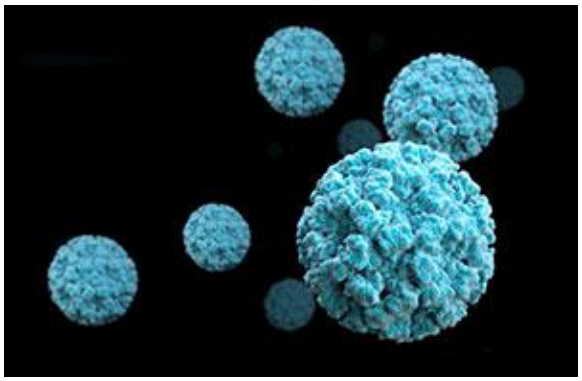
Early photo of the interior of the Janesville Water Works, ca. 1921. Around this time, many American municipalities were adopting practices that dramatically improved drinking water quality. *Photo: Bill Tunstead*

Today, public sanitary sewer systems, private septic systems, and drinking water disinfection are well established so the risk of illness and mortality from waterborne disease in the United States is greatly reduced compared to 100 years ago. Protecting groundwater from microbial contamination remains a top public health priority since outbreaks of gastrointestinal illness related to well water still occur periodically. A notable example is the 2007 outbreak of norovirus caused by contaminated well water which sickened 229 diners and staff at a Door County restaurant (Borchardt et al., 2011). Because effects can be acute and severe, multiple barriers are the best defense.

In general, waterborne disease outbreaks like this are related to how quickly pathogens travel through the soil. Often, pathogen movement is slow enough or occurs over sufficiently great distances that natural attenuation and degradation make the pathogen ineffective by the time it has traveled from a fecal waste source (e.g., septic field, leaking sanitary sewer, or manure at the land surface) to a drinking water well. However, this is not always the case, particularly in areas with thin soils or shallow water tables. Furthermore, different pathogens move through the soil differently, so the presence or absence of one pathogen (e.g. a type of bacteria) does not always correlate with the presence or absence of others (e.g. viruses). Because of the complicated nature of pathogen transport and the serious consequences of waterborne disease outbreaks, the Groundwater Coordinating Council (GCC) regularly prioritizes research that evaluates how, when, and where pathogens in groundwater may pose a threat to public health.

GCC in Action: *Viruses in Drinking Water*

It is difficult and expensive to comprehensively test for all harmful pathogens, so water samples are typically tested for “indicators” – microbes that are not necessarily harmful themselves, but are a warning sign that other, potentially harmful microbial agents may be present. Traditionally, the presence of coliform bacteria is assumed to be a reasonable indicator of the presence of most harmful microbial agents, including viruses. Since 2000, groundbreaking work by GCC agencies related to the occurrence of viruses in drinking water and the impact on human health have challenged these assumptions.



Norovirus, one of the human enteric viruses detected in drinking water by GCC researchers. *Image: CDC*

An early indication of the significance of the problem came in the early 2000s, when researchers at the Marshfield Clinic Research Foundation demonstrated that viruses in private wells do not exhibit strong seasonal trends and are not correlated with commonly used indicators such as total coliform and fecal enterococci (Borchardt et al., 2003a and 2003b). A subsequent study with the U. S. Geological Survey (USGS) looking at LaCrosse municipal wells drew similar conclusions and further concluded that nearby surface waters were not the source for the viruses; rather, viruses in LaCrosse wells were likely coming from leaking sanitary sewers (Borchardt et al., 2004; Hunt et al., 2005). This was not shocking in a city like LaCrosse, where municipal wells are located in a shallow sand and gravel aquifer, relatively close to underground pipe infrastructure. However, municipal wells completed at depth – below confining layers of shale that separate shallow from deep aquifers – were presumed to be well-protected. The geology in the Madison area meets this description, yet collaborators from the Marshfield clinic, the Wisconsin Geological and Natural History Survey (WGNHS), and the University of Waterloo discovered human enteric viruses in Madison municipal wells in 2007, indicating that all aquifers are potentially vulnerable to microbial contamination (Borchardt et al., 2007; Bradbury et al. 2013).

In recognition that disinfection with chlorine or ultraviolet light can dramatically reduce virus populations, a subsequent study compared drinking water quality and illnesses in Wisconsin communities that do not disinfect. This work concluded that 6% to 22% of gastrointestinal illness incidents were directly attributable to viruses in drinking water in these communities (Borchardt et al., 2012). Results were so compelling that the Department of Natural Resources (DNR) quickly developed a rule mandating disinfection of municipal drinking water, although this was repealed by the state legislature in 2011.

This series of studies exemplifies how work by GCC researchers positions Wisconsin at the cutting edge of protecting the environment, economy, and public health. Nationally, the Environmental Protection Agency (EPA) included virus types found in the Wisconsin studies on the list of 30 unregulated contaminants that were monitored from 2013 to 2015 in 6,000 public water systems across the United States in order to gather information to support future drinking water protection. Continued research along these lines follows in the footsteps of the great public health advances of 100 years ago to ensure that drinking water, a basic human need, is not jeopardizing public health.

Other Projects in Other Places

Tracking the source of bacteria

Until recently, definitively identifying the cause of bacterial contamination in drinking water wells was not always possible. Many projects funded by the Wisconsin Groundwater Research and Monitoring Program have developed new techniques for detecting, quantifying, and monitoring microorganisms in groundwater and soils. Impressive results include a rapid molecular method to identify contamination from human waste without culturing organisms, a reliable method for detecting *Heliobacter pylori* in environmental samples, and an assay that distinguishes fecal pollution from grazing animals like cows from other sources like pigs or chickens. Improved laboratory methods enhance the ability of GCC agencies to quickly understand the root causes of bacterial contamination and identify appropriate solutions.

Laboratory methods that can distinguish fecal pollution from grazing animals vs. human or other animal sources are among of the cutting edge research supported by the GCC. *Photo:* *DNR*

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